New research suggests that near-Earth encounters can 'shake' asteroids

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(PhysOrg.com) -- For decades, astronomers have analyzed the impact that asteroids could have on Earth. New research by MIT Professor of Planetary Science Richard Binzel examines the opposite scenario: that Earth has considerable influence on asteroids — and from a distance much larger than previously thought. The finding helps answer an elusive, decades-long question about where most meteorites come from before they fall to Earth and also opens the door to a new field study of asteroid seismology.

Astronomers have worried about the impact that asteroids could have on Earth ever since a theory was proposed in the 1980s that a giant asteroid likely caused the extinction of the dinosaurs 65 million years ago. New research by MIT Professor of Planetary Science Richard Binzel examines the opposite scenario: that Earth has considerable influence on asteroids — and from a distance much larger than previously thought.

By analyzing telescopic measurements of near-Earth asteroids (NEAs), or asteroids that come within 30 million miles of Earth, Binzel has determined that if an NEA travels within a certain range of Earth, roughly one-quarter of the distance between Earth and the moon, it can experience a "seismic shake" strong enough to bring fresh material called "regolith" to its surface. These rarely seen "fresh asteroids" have long interested astronomers because their spectral fingerprints, or how they reflect different wavelengths of light, match 80 percent of all meteorites that fall to Earth, according to a paper by Binzel appearing in the Jan. 21 issue of Nature. The paper suggests that Earth's gravitational pull and tidal forces create these seismic tremors.

By hypothesizing about the cause of the fresh surfaces of some NEAs, Binzel and his colleagues have tried to solve a decades-old conundrum about why these fresh asteroids, known as Q-types, are not seen in the main asteroid belt, which is between Mars and Jupiter. They believe this is because the fresh surfaces are the result of a close encounter with Earth, which obviously wouldn't be the case with an object in the main asteroid belt. Only those few objects that have ventured recently inside the moon's orbital distance, about one-quarter of the distance between Earth and the moon, and have experienced a "fresh shake" match freshly fallen meteorites measured in the laboratory, Binzel says.

Clark Chapman, a planetary scientist at the Southwest Research Institute in Colorado, believes Binzel's work is part of a "revolution in asteroid science" over the past five years that considers the possibility that something other than collisions can affect asteroid surfaces. "For decades, it was thought that the sizes, shapes and spin period of asteroids were all caused by collisions between asteroids, and that this could explain everything that has happened to them in the past 4 billion years," he says. "This work is one more perspective in this revolution of thinking about these very weird rubble piles, and what's affecting them."

The ordinary chondrite problem

Although it is believed that meteorites come from asteroids, astronomers and meteorite scientists have struggled for 30 years to figure out why asteroids matching the majority of all meteorites that fall to the Earth, known as ordinary chondrites, could not be found in space. The discrepancy emerged when scientists began measuring the spectral fingerprints of meteorites in the lab to determine their mineral constituents based on how they reflect light of different wavelengths. Around the same time, astronomers began using telescopes to measure how asteroids reflect light of varying wavelengths. Because meteorites are thought to originate from asteroids, it was expected that the spectral fingerprints would match.

Instead, scientists found asteroids with spectral fingerprints that were muted and had a reddish tint. These asteroids, known as S-types, appear "sunburned," according to Binzel, due to the space weathering process of solar wind that physically damages their mineral structure.

It wasn't until last year that astronomers could estimate the exposure time of the space weathering process when co-author Pierre Vernazza determined that it takes solar wind a million years to redden an asteroid. "In astronomy, this is nothing, it's like yesterday," Binzel explains. Vernazza's findings, he notes, suggested that astronomers should never see fresh asteroids, since the weathering process is so "brief."

And yet they've been observing Q-types among NEAs for 25 years — suggesting there is something about their proximity to Earth that freshens their surface at a rate that is faster than the space weathering process. That something, Binzel believes, is the seismic shake-up caused by Earth's tidal stress and gravitational pull.

Making the connection

For a decade, Binzel's team has used a large NASA telescope in Hawaii to collect information on NEAs, including a huge amount of spectral fingerprint data. Using this data, as well as estimates based on numerical calculations, Binzel's team examined where a sample of 95 NEAs had been during the past 500,000 years, tracing their orbits to see how close they'd come to Earth. They discovered that 75 NEAs in the sample had passed well inside the moon's distance within the past 500,000 years, including all 20 Q-types in the sample.

Using a calculation known as Minimum Orbit Intersection Distance (MOID), Binzel next determined that an asteroid traveling within a distance equal to 16 times the Earth's radius (about one-quarter of the distance to the moon) appears to experience vibrations strong enough to create fresh surface material. He reached that figure based on his finding that one-quarter of NEAs are fresh, as well as two known facts — that space weathering can happen in less than one million years, and that about one-quarter of all NEAs come within 16 Earth radii in one million years.

Before now, people thought an asteroid had to come within one to two Earth radii, a distance known as the Roche limit, to undergo significant physical change.

Shaking up asteroid seismology

Many details about the shaking process remain unknown, including what exactly it is about Earth that shakes the asteroids, and why this happens from a distance as far away as 16 Earth radii. What is certain is that the conditions depend on complex factors such as the velocity and duration of the encounter; the asteroid's shape, internal structure, surface gravity and rotation rate; and the nature of the preexisting regolith. “The exact trigger distance depends on all those seismology factors that are the totally new and interesting area for cutting edge research,” Binzel says.

Further research might include computer simulations, ground observations and sending probes to look at the surfaces of asteroids. “We don’t know yet what more than a handful of these objects look like,” Chapman says of the Q-types. He predicts theoreticians will put together models about the behavior of these asteroids to help scientists better understand Binzel’s research.

Binzel’s next steps will be to try to discover counterexamples to his findings or additional examples to support it. He may also investigate whether other planets like Venus or Mars affect asteroids that venture close to them.

His research will be tested in 2029 when the asteroid Apophis is expected to travel within a distance equal to six times the Earth’s radius. Anyone with binoculars in Europe or Africa will be able to conduct a simple test to see whether the close encounter makes the surface of the weathered asteroid appear less red. “It should certainly be changed in this fashion if the Binzel observation is interpreted correctly,” Chapman says.

More information: "Earth encounters as the origin of fresh asteroid surfaces," by R. Binzel, A. Morbidelli, S. Merouane, F. DeMeo, M. Birlan, P. Vernazza, C. Thomas, A. Rivkin, S. Bus and A. Tokunaga, in *Nature*, published online Jan. 21, 2010.

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